



CALIFORNIA'S STEM CELL AGENCY

CIRM-FUNDED CLINICAL TRIALS

NOVEMBER 2017

AMYOTROPHIC LATERAL SCLEROSIS, ALS

(Also known as Lou Gehrig's disease)

Cedars-Sinai Medical Center

Team Lead: Clive Svendsen

A team at Cedars-Sinai is transplanting millions of genetically engineered stem cells into patients with a degenerative nerve disease called ALS. When transplanted, these cells become astrocytes, the support cells that keep nerve cells functioning. Due to the genetic modifications, the cells also deliver high doses of a growth factor which has been shown to protect nerve cells. The goal of this early stage trial is to test the safety of this astrocyte replacement strategy in ALS patients.

BrainStorm Cell Therapeutics

Team Lead: Ralph Kern

BrainStorm Therapeutics is using mesenchymal stem cells that are taken from the patient's own bone marrow. These stem cells are then modified to boost their production of neurotrophic factors, which are known to help support and protect neurons, the cells destroyed by ALS. The CIRM funding will enable the company to test this therapy, called NurOwn®, in a Phase 3 trial involving about 200 patients.

ALPHA THALASSEMIA MAJOR

UC San Francisco

Team Lead: Tippi MacKenzie

Dr. MacKenzie is using hematopoietic stem cells (HSCs) to treat babies in the womb who have alpha thalassemia major, a blood disorder that is almost always fatal. The HSCs are taken from the mother's bone marrow and transplanted into the baby before birth. The mother's cells are able to survive and correct the defect in the baby's blood cells, increasing the chances of a healthy birth and improving the chances of having effective treatments after birth.

CANCER

Blood cancers

Angiocrine Biosciences

Team Lead: Paul Finnegan

The Angiocrine team is developing a cell therapy aimed to improve the availability and engraftment of blood stem cell transplants for cancer patients who have had their cancerous bone marrow removed by chemotherapy. The cell therapy is made of blood stem cells and endothelial cells, which line blood vessels and are thought to improve the engraftment of the stem cell transplant. The hope is that this treatment will provide a safer, more tolerable and effective stem cell transplantation that will rebuild the patient's immune system cancer-free.

Forty Seven, Inc.

Team Lead: Mark Chao

Forty Seven Inc. is conducting a Phase 1b clinical trial for acute myeloid leukemia patients. Leukemia stem cells have a protein on their surface that enable them to

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evade being identified and destroyed by the patient's own immune system. This protein also helps these leukemia stem cells survive traditional therapies such as chemotherapy, enabling the cancer to lie dormant for a period before returning and causing the patient to relapse. The team is using a combination of a monoclonal antibody and the drug Azacitidine to make the leukemia stem cells vulnerable to being attacked and destroyed by the immune system.

Nohla Therapeutics Inc.**Team Lead: Colleen Delaney**

Nohla Therapeutics is testing a hematopoietic stem cell and progenitor cell therapy called NLA101 to help patients suffering from neutropenia, a condition that leaves people susceptible to deadly infections, after receiving chemotherapy for acute myeloid leukemia (AML). The company is currently launching a Phase 2 trial to test this treatment in adult AML patients that have received high-dose chemotherapy.

Brain cancer (malignant glioma)**City of Hope****Team Lead: Christine Brown**

A team at the City of Hope led by Dr. Christine Brown is pursuing a Phase 1 trial targeting an aggressive brain cancer called malignant glioma. City of Hope will re-engineer a patient's immune system central memory T cells (TCM cells) to express chimeric antigen receptors (CAR). These CAR-T cells will recognize a molecular marker on the surface of glioma cancer stem cells and kill the tumors. Dr. Brown's award to pursue CAR-T therapy for solid cancers comes at an exciting and opportune time with the recent U.S. Food and Drug Administration (FDA) approval of the first CAR-T therapy, called Kymriah, for patients with acute lymphoblastic leukemia, a deadly form of blood cancer.

Leukemia**UC San Diego (2 clinical trials)****Team Lead: Thomas Kipps**

A team at UCSD is testing an antibody therapy called cirmtuzumab in a clinical trial study to treat a blood cancer, Chronic Lymphocytic Leukemia (CLL). The antibody recognizes and attaches to a protein on the surface of cancer stem cells. This attachment disables the protein which slows the growth of the leukemia and makes it more vulnerable to anti-cancer drugs. The team is also testing cirmtuzumab in combination with an approved cancer fighting drug called ibrutinib, to target cancer stem cells in a separate clinical trial. The aim is that combining cirmtuzumab with ibrutinib will improve cancer remission and long-term cancer control in patients.

Multiple Myeloma**Poseida Therapeutics****Team Lead: Matthew Spear**

Poseida Therapeutics is testing the safety of a gene modified cell therapy to treat

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multiple myeloma, the abnormal growth of malignant plasma cells of the immune system. The company's technology is seeking to destroy these cancerous myeloma cells with an immunotherapy approach that uses the patient's own engineered immune system T cells to seek and destroy the myeloma cells.

Skin cancer and other hard-to-treat cancers**UCLA****Team Lead: Antoni Ribas**

There are few options for patients whose cancers have metastasized, or spread, due to resistance to current therapies. This team is using gene editing technology to modify a patient's own immune system cells and blood-forming stem cells with the aim of creating a continuous supply of immune cells that can recognize and attack hard-to-treat cancers.

Solid tumors**UCLA****Team Lead: Dennis Slamon**

A team at UCLA is testing a drug for the treatment of cancer that works by blocking PLK4, a protein that is important in regulating cell growth, division and death. This protein is important for the survival of the cancer stem cell as well as the rest of the cells in a tumor. It is hypothesized that blocking this protein from working in the tumor may stop or even shrink tumor growth.

Solid tumors/Colorectal cancer**Forty Seven, Inc.****Team Lead: Mark Chao**

Forty Seven, Inc. has developed an antibody therapy to block a protein called CD47 that is found on the surface of cancer cells. CD47 acts as a 'don't eat me' signal that tells immune cells not to eliminate the cancer cells. When this 'don't eat me' signal is blocked by the antibody, the cancer cells are 'eaten' and eliminated by the patient's immune cells. Forty Seven, Inc. will combine the anti-CD47 antibody with cetuximab – a drug used in the treatment of solid tumors – to treat patients with advanced colorectal cancer, hitting it with a 1-2 punch to kill the tumors and prevent any recurrence.

CHRONIC GRANULOMATOUS DISEASE**UCLA****Team Lead: Donald Kohn**

Chronic granulomatous disease is a rare immune disorder that results in severe, recurrent infections that can impact quality and length of life. A team at UCLA uses the patient's own genetically modified blood stem cells to create a new blood supply and a healthy immune system, with the aim of curing patients with this disease.

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DIABETES**ViaCyte, Inc. (2 clinical trials)****Team Lead: Howard Foyt**

ViaCyte is developing cell therapies to replace lost beta cells for people with type 1 diabetes (T1D). The therapies are derived from human embryonic stem cells, which are partially matured into becoming pancreatic tissues (the type destroyed in T1D). The cells are inserted into a small pouch that is transplanted under the patient's skin. The transplanted cells will develop into fully matured beta cells that secrete the hormone insulin, which is needed to keep blood sugar levels at a healthy level. CIRM is funding ViaCyte's two Phase 1/2 trials testing different product candidates. The first product, VC-01, encapsulates the cells and protects them from the patient's immune system. The second product, VC-02, allows the patient's blood vessels to make direct contact with the implanted cells. VC-02 is being developed for patients with high-risk T1D.

Caladrius Biosciences**Team Lead: Douglas Losordo**

Researchers at Caladrius Biosciences will take cells, called regulatory T cells (Tregs), from the patient's own immune system, expand the number of those cells in the lab and return them to the patient to reduce the autoimmune attack on the insulin-producing cells in people with type 1 diabetes.

HEART DISEASE**Duchenne Muscular Dystrophy-Associated Heart Disease****Capricor Therapeutics****Team Lead: Deborah Ascheim**

Capricor is using donor cells derived from the heart to treat patients suffering from Duchenne Muscular Dystrophy (DMD), a genetic disorder that leads to progressive muscle degeneration, including heart muscle. One of the leading causes of death for children with DMD is heart failure and the aim of this treatment is to help improve heart muscle outcomes for these patients.

HIV/AIDS**Calimmune, Inc.****Team Lead: Geoff Symonds**

Calimmune is genetically modifying patients' own blood-forming stem cells (also known as bone marrow stem cells) so they can produce immune cells—the ones normally destroyed by the virus—that cannot be infected by the virus. The goal of this treatment is enable the patients to clear their systems of the virus, effectively curing the disease.

City of Hope and Sangamo Therapeutics**Team Lead: John Zaia**

A team at City of Hope and Sangamo Therapeutics is testing a similar method to functionally cure people with HIV. But while Calimmune is using a technique called

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RNA interference to block the virus, City of Hope/Sangamo are using a technology called zinc finger nuclease – a kind of molecular scissors – to snip out the target gene.

AIDS-related lymphoma

UC Davis

Team Lead: Mehrdad Abedi

A team at UC Davis is taking a patient's blood forming stem cells and inserting three anti-HIV genes into them and then returning them to the individual to help rebuild their immune system. The anti-HIV genes are then passed on to all new immune system cells and make them resistant to HIV. Because AIDS-related lymphoma is linked to the constant immune cell stimulation caused by HIV infection, getting rid of the virus should prevent return of the cancer.

KIDNEY DISEASE**Kidney failure**

Stanford University

Team Lead: Samuel Strober

A team at Stanford University will work with kidney transplant patients to see if injecting blood stem cells and T cells (which play an important role in the immune system) from the kidney donor into the kidney recipient can enable the recipient to bypass the need for a life-long dependence on immunosuppressant drugs.

Dialysis

Humacyte, Inc. (2 clinical trials)

Team Lead: Jeffrey Lawson

Humacyte is using donor cells to create a bioengineered vein needed by people undergoing hemodialysis, the most common form of dialysis. In dialysis a person is connected to a machine that removes waste from their blood. The bioengineered vein is implanted in the arm and used to carry the patient's blood to and from their body during dialysis. Over time the patient's own stem cells start to populate this vein, in effect making it part of the patient's own body. In two separate clinical trials, the Humacyte product is being compared head-to-head with the current standard of care as well as a synthetic product that is used by some patients who are not candidates for the standard treatment.

MACULAR DEGENERATION

University of Southern California

Team Lead: Mark Humayun

Regenerative Patch Technologies and scientists at the University of Southern California and UC Santa Barbara, are growing specialized cells of the retina from embryonic stem cells, placing them on a single layer scaffold and implanting the combination device in the back of the eye to try to reverse blindness.

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OSTEOARTHRITIS

California Institute for Biomedical Research

Team Lead: Leonardo Sahelijo

Researchers at the California Institute for Biomedical Research (CALIBR) have been awarded \$8.447 million to test KA34, a drug that, in preclinical tests, recruits stem cells to create new cartilage in areas damaged by osteoarthritis. CIRM funded the research that developed this technology and now this Phase 1 trial will test this stem cell directed treatment in people with osteoarthritis of the knee, hopefully slowing down or even halting the progression of the disease.

OSTEONECROSIS

UC Davis

Team Lead: Nancy Lane

A team at UC Davis is testing a drug that directs bone stem cells to the surface of the bone where they then develop new bone tissue and stimulate new blood vessel formation, two defects underlying osteonecrosis. Should this drug prove safe and show signs of effectiveness, it may be tested for the treatment of other bone diseases like osteoporosis.

PULMONARY HYPERTENSION

Cedars-Sinai Medical Center

Team Lead: Michael Lewis

A team at Cedars-Sinai Medical Center is using donor cells derived from the heart to reduce two hallmark symptoms of pulmonary hypertension: inflammation and high blood pressure in the blood vessels within the lungs. These conditions make the heart struggle to pump blood to the lungs and over time can ultimately lead to heart failure. The aim of this treatment is to delay the progression of the disease.

RETINITIS PIGMENTOSA

UC Irvine and jCyte, Inc. (2 clinical trials)

Team Lead: Henry Klassen

A team at UC Irvine, is using cells called retinal progenitor cells to repair the damage caused by this vision destroying disease. The cells are injected into the back of the eye and it's hoped they will help preserve the photoreceptors attacked by RP as well as generate new photo receptors to replace those destroyed by the disease. We funded the Phase 1 clinical trial and are now funding Phase 2.

SEVERE COMBINED IMMUNODEFICIENCY (SCID)

UCLA

Team Lead: Donald Kohn

A team at UCLA is using a patient's own blood stem cells to try and repair their damaged immune system. They will use what's called a lentiviral vector to deliver genetic material into the blood stem cells, correcting the genetic flaw that causes SCID. It's hoped this will create a new blood system and a healthy immune system.

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SEVERE COMBINED IMMUNODEFICIENCY (SCID) - Continued**Stanford University****Team Lead: Judith Shizuru**

A team at Stanford proposes to replace SCID patients' dysfunctional immune cells with healthy ones using a safer form of bone marrow transplant (BMT). Current BMT procedures must use toxic chemotherapy to make space in the bone marrow for the healthy transplanted stem cells to engraft. The Stanford team will instead test a safe, non-toxic protein that targets and removes the defective blood forming stem cells. If successful, the procedure could open up similar BMT therapies to patients with other auto-immune diseases such as multiple sclerosis, lupus or diabetes that are generally not candidates for BMT currently.

St. Jude Children's Research Hospital**Team Lead: Brian Sorrentino**

St. Jude Children's Research Hospital is teaming up with UC San Francisco to repair the damaged immune system of children born with SCID. They will genetically modify the patient's own blood stem cells, with the goal of creating a new blood system and restoring the health of the immune system.

SICKLE CELL ANEMIA**UCLA****Team Lead: Donald Kohn**

A team at UCLA is genetically modifying a patient's own blood stem cells to produce a correct version of hemoglobin, the protein that is mutated in these patients, which causes abnormal sickle-like shaped red blood cells. These misshapen cells lead to dangerous blood clots, debilitating pain and even death. The genetically modified stem cells will be given back to the patient to create a new sickle cell-free blood supply.

SPINAL CORD INJURY**Asterias Biotherapeutics****Team Lead: Jane Lebkowski**

Asterias Biotherapeutics uses cells derived from embryonic stem cells to heal the spinal cord at the site of injury. They mature the stem cells into cells called oligodendrocyte precursor cells that are injected at the site of injury where it is hoped they can repair the insulating layer, called myelin, that normally protects the nerves in the spinal cord.

STROKE**SanBio****Team Lead: Damien Bates**

SanBio is carrying out a Phase 2 clinical trial using mesenchymal stem cells (MSCs) to help people suffering from chronic disability following a stroke. The MSCs are isolated from the bone marrow of healthy adult donors, and then modified to enhance their ability to promote recovery from injury by triggering the brain's natural

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regenerative ability. Patients with stroke can suffer from loss of mobility in certain parts of their body and the hope is that this therapy will rescue some of these problems.

VIRAL INFECTION

Children's Hospital of Los Angeles

Team Lead: Michael Pulsipher

Viral infection can lead to fatal complications in patients with weakened immune systems resulting from chemotherapy, bone marrow or cord blood transplant, and other forms of inherited or acquired disorders. A team at Children's Hospital of Los Angeles is testing the feasibility of providing these immune suppressed patients with engineered T-cells to fight these viruses. Donated virus-specific T-cells will be matched to the patient's immune system to help boost their ability to fight off these viruses and to provide longer-term anti-viral protection.

CLOSED CLINICAL TRIALS

CANCER

Brain Cancer (Glioblastoma)

ImmunoCellular Therapeutics is targeting six proteins that are found on the surface of cancer stem cells in glioblastoma, a brain cancer. Immune cells from the patient's own immune system are exposed to fragments of these cancer cell proteins in the lab. When returned to the patient's body, these immune system cells can now help the patient's immune system identify, and then hopefully kill, the cancer stem cells responsible for the tumor's recurrence and growth. This Phase 3 trial was suspended in June 2017 due to lack of sufficient financial resources.

Metastatic Skin Cancer (Melanoma)

NeoStem, which later changed its name to Caladrius BioScience, ran a Phase 3 trial targeting cancer stem cells. These cells are believed to be able to survive chemotherapy and other cancer-targeting treatments, and can cause a relapse by enabling tumors to grow and spread. This approach used the patient's own tumor cells to create a personalized therapy, one designed to engage the patient's own immune system and destroy the cancer. The trial was halted by Caladrius in January 2016 for business reasons.

Solid Tumors/Acute myeloid leukemia

A team at Stanford University is using a molecule known as an antibody to target cancer stem cells. This antibody can recognize CD47, a protein the cancer stem cells carry on their cell surface. The cancer cells use that protein to evade the component of our immune system that routinely destroys tumors. By disabling this protein, the team hopes to empower the body's own immune system to attack and destroy the cancer stem cells. The clinical trial testing this therapy has concluded and has led to another CIRM-funded trial by Forty-Seven, Inc.

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SPINAL CORD INJURY

Geron carried out a Phase 1 clinical trial to assess the safety and preliminary activity of escalating doses of human embryonic stem cell (hESC) derived oligodendrocyte progenitor cells for treatment of spinal cord injury. Five patients were treated, all safely and without any serious side effects, before the trial was halted by Geron for financial reasons. The work in this trial later has since been revived by Asterias.

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